CHAPTER 3

HORIZONTAL CONSTRUCTION

The construction of roads and airfields, or portions of roads and airfields, is often tasked to the Seabees for accomplishment. As an Engineering Aid, you can expect involvement in projects of this type. This involvement may include assisting the engineering officer in the design of these facilities or in the surveying operations required before, or during, construction. Whatever your involvement is, you must be familiar with the terminology, methods, and materials of road and airfield construction. This chapter will provide that familiarity.

ROADS

A military road is defined as any route used by the military for transportation of any type. This includes everything from a superhighway to a simple path through the jungle. The type of road required depends mainly upon the missions of the units that use it. In forward combat zones, the requirements are usually met by the most expedient road; that is, one that will get the job done with no attempt for permanency. In the rear zones, however, the requirements usually call for some degree of permanency and relatively high construction standards.

NOMENCLATURE

When assigned to the engineering division, you may help prepare the working plans for the construction of roads and airfields; for example, a two-lane, earth, gravel, or paved-surface road. Figures 3-1 and 3-2 show the basic parts of a road. The following paragraphs give

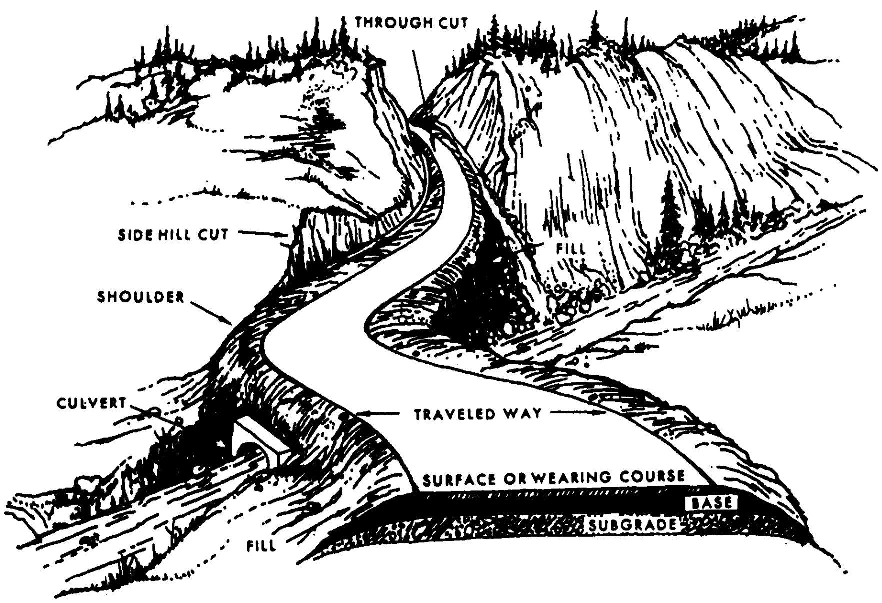


Figure 3-1.-Perspective of road showing road nomenclature.

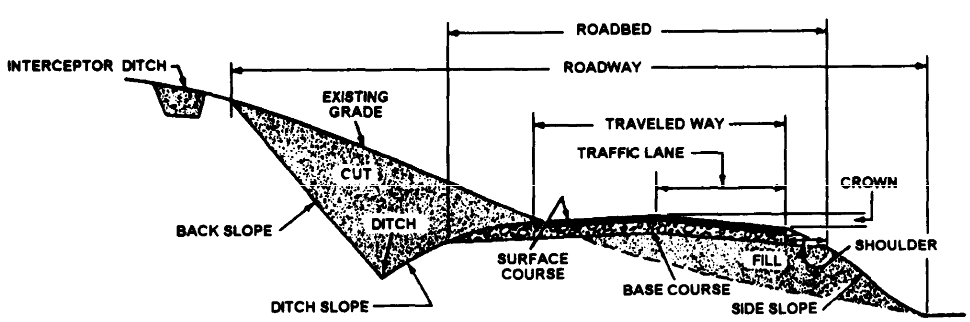


Figure 3-2.—Typical cross section showing road nomenclature.

definitions of some terms that you are likely to use when preparing the working plans for a road:

1. CUT. Has two connotations: (1) an excavation through which the road passes and (2) the vertical distance the final grade is below the existing grade.

2. **FINAL, OR FINISHED, GRADE.** The elevation to which the road surface is built.

3. **SURFACE.** That portion of the road that comes into direct contact with traffic.

4. **EXISTING GRADE.** The undisturbed earth before construction begins.

5. **FILL.** Has two connotations: (1) earth that has been piled up to make the road and (2) the vertical distance the final grade is above the existing grade.

6. **SUBGRADE.** The foundation of a road which can be either undisturbed earth (for a cut) or material placed on top of the existing grade.

7. **BASE.** Select material (crushed stone, gravel, etc.) placed in a layer over the subgrade for the purpose of distributing the load to the subgrade.

8. **TRAFFIC LANE.** That portion of the road surface over which a single line of traffic traveling in the same direction will pass.

9. **TRAVELED WAY.** That portion of the roadway upon which all vehicles travel (both lanes for a two-lane road).

10. **SHOULDERS.** The additional width immediate y adjacent to each side of the traveled way.

11. **ROADBED.** The entire width (including the traveled way and the shoulders) upon which a vehicle may stand or travel.

12. **ROADWAY.** The entire width that lies within the limits of earthwork construction.

13. **ROADWAY DITCH.** The excavation, or channel, adjacent and parallel to the roadbed.

14. **DITCH SLOPE.** The slope that extends from the outside edge of the shoulder to the bottom of the ditch. (Sometimes called **front slope** or **side slope.)**

15. **BACK SLOPE.** The slope from the top of the cut to the bottom of the ditch (Sometimes called **cut slope.)**

16. **FILL SLOPE.** The slope from the outside edge of the shoulder to the toe of the fill. (Also, sometimes called **front slope** or **side slope.)**

17. **TOE OF SLOPE.** The extremity of the fill (where the existing grade intercepts the fill).

18. **INTERCEPTOR DITCH.** A ditch cut to intercept the water table or any subsurface drainage. Also, a ditch cut along the top of fills to intercept surface drainage.

19. **WIDTH OF CLEARED AREA.** The width of the entire area that is cleared for the roadway.

20. **SLOPE RATIO.** A measure of the relative steepness of the slope, expressed as the ratio of the horizontal distance to the vertical distance.

21. **CENTER LINE.** The exact center, or middle, of the roadbed.

22. **BLANKET COURSE.** A 1- or 2-inch layer of sand or screening spread upon the subgrade to prevent mixing of base and subgrade.

23. **CROWN.** The difference in elevation between the center line and the edge of the traveled way.

24. **SUPERELEVATION.** The difference in elevation between the outside and inside edge of the traveled way in a horizontal curve.

25. **STATION.** A horizontal distance generally measured in intervals of 100 feet along the centerline.

26. **STATION NUMBER.** The total distance from the beginning of construction to a particular point (for example, 4 +58 is equal to 458 feet).

SURVEY

When it is decided that a road is needed through a particular area, the first and logical step is to determine a route for it to follow. This mute may be chosen by the use of maps, aerial photographs, aerial reconnaissance, ground vehicle reconnaissance, walk-through reconnaissance, or by any combination of these. Once the route is chosen, a surveying crew makes the preliminary survey. This survey consists of a series of traverse lines connecting a series of traverse stations.

A survey party will stake in each of the traverse stations and determine the bearing and distance of the connecting traverse lines. From this information, an Engineering Aid will draw the **points of intersection** (PI) and the connecting lines. Then an engineer will compute the horizontal curves at each point of intersection, and an Engineering Aid will draw the curves and mark the stationing. This drawing is the proposed center line.

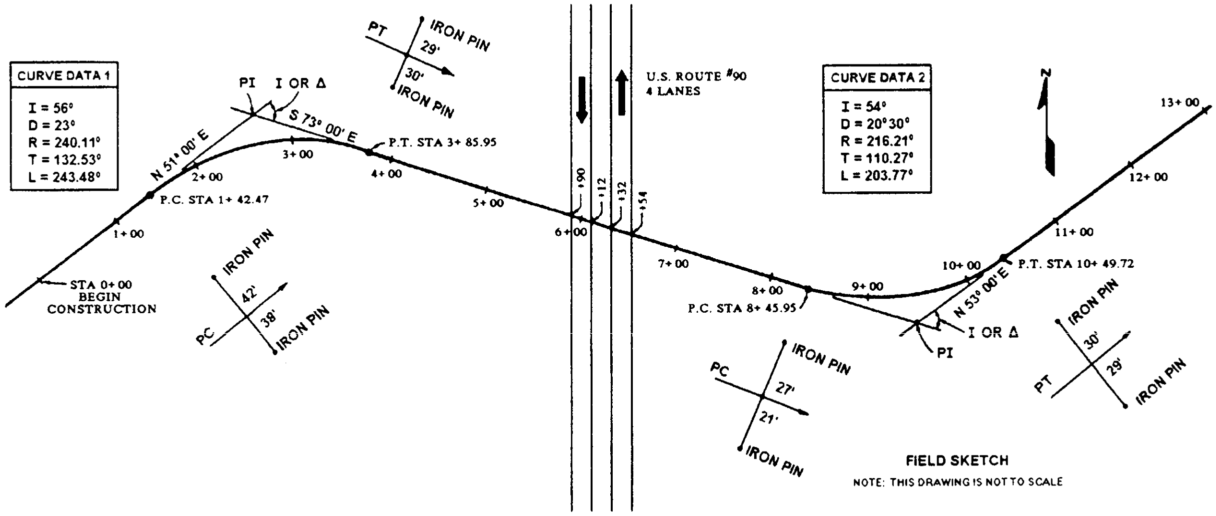


Figure 3-3.—The road plan.

The drawing of the proposed center line is then given to a final location party, which stakes in the center line and curves. With the approval of the engineer, the party chief may make changes in alignment of the center line, but the changes must be recorded.

Once the final location is determined, all information and changes pertinent to the location are used to prepare a second and final drawing, showing the final center-line location, construction limits, all curves and curve data, station marks, control points, natural and man-made terrain features, trees, buildings, and anything else that is helpful in construction. This drawing, known as a **road plan** (fig. 3-3), is a "bird's-eye view" of the road and shows what you should see from a position directly above. The road plan is drawn on the upper portion of plan-and-profile paper, using any scale desired. The bottom portion of the plan-and-profile paper, which, as you know, is composed of grid lines, is reserved for drawing the road profile.

ROAD PLAN

The road plan, or plan view, shows the actual location and length of the road measured along the center line. The length is determined by station points, which are set at full station (full stations are 100 feet or 100 meters apart), half station, or one-tenth station intervals. Odd-station points are set at major breaks in the terrain. Referring to figure 3-3, you see the manner in which the beginning station (0 + 00) is shown, and you also see the manner in which the full stations and the partial stations are shown. Recalling your study of the EA3 TRAMAN, you know, then, that the distance from the beginning station to the last full station shown (13 + 00) is 1,300 feet.

All man-made and natural objects, such as trees, buildings, fences, wells, and so on, are also plotted on the plan if they are in the right-of-way or construction limits. (Right-of-way is the land acquired for the road construction.) Identification and location of these objects are taken from the surveyor's notebook Their location is determined by a station number and distance from the center line. All measurements and distances are made perpendicular to the center line of the particular station unless otherwise noted.

Horizontal Curves

The road center line consists of straight lines and curves. The straight lines are called tangents, and the curves are called horizontal curves. These curves are used to change the horizontal direction of the road. All information necessary to draw a curve should be furnished by the engineer or taken from the surveyor's notebook. The necessary information is known as curve data. Below is the data for curve No. 1 in figure 3-3 and an explanation of the terms.

Δ = 56°00'

D = 23°00'

R = 240.11'

T = 132.53'

L = 243.48'

1. The symbol Δ (Delta), or the symbol I, represents the **intersecting angle,** which is the deflection angle made by the tangents where they intersect.

2. D is the **degree of curvature,** or **degree of curve.** It is the angle subtended by a 100-foot arc or chord (to be discussed in chapter 11 of this TRAMAN).

3. R is the **radius** of the curve, or arc. The radius is always perpendicular to the curve tangents at the **point of curvature (PC)** and the **point of tangency** (PT).

4. T is the **tangent distance,** which is measured from the PI to the PC and the PT. The PC is the beginning of the curve, and the PT is the end of the curve.

5. L is the **length of the curve** measured in feet along the curve from the PC to the PT.

A horizontal curve is generally selected to fit the terrain. Therefore, some of the curve data will be known. The following formulas show definite relationships between elements and allow the unknown quantities to be computed:

1. To find the radius (R), or degree of curvature (D), use the following formula:

$$R = \frac{5729.58}{D}$$

2. To find the tangent distance (T), compute as follows:

$$T = R \tan \frac{\Delta}{2}$$

3. To find the length of curve (L), use the following formula:

$$L = 100 \frac{\Delta}{D} \text{ (D and } \Delta \text{ in degrees)}$$

The PC and PT are designated on the plan by a partial radius drawn at each point and a small circle on the center line. The station numbers of PC and PT are noted as shown in figure 3-3. The length of the curve (L) is added to the PC station to obtain the station of the PT. The curve data is noted on the inside of the curve it pertains to and is usually between the partial radii.

Since most horizontal curves have superelevation (that is, the outside edge of the traveled way is higher than the inside edge), there must be a transition distance in which the shape of the road surface changes from a normal crown to a superelevated curve. The transition length is generally 150 feet and starts 75 feet before the PC is reached. The same is true in leaving curves. The transition begins 75 feet before the PT and ends 75 feet beyond. The beginning and end of the superelevation are noted on the plan.

Control Points

A control point maybe a PT, PC, PI, or a point on tangent (POT). Since these control points may be destroyed during construction, you must reference them to other points. In the field, a common practice that you should use is to drive iron pins or other reference stakes at right angles to the control point on each side of the center line, and then measure and record the distance from the pins to the control point. If room allows, these reference points should be drawn on the road plan opposite the control points, as shown in figure 3-3. If not, you should show the control points and references on a separate sheet, called a reference sheet.

ROAD PROFILE

The procedure used to plot road profiles is discussed in chapter 7 of the EA3 TRAMAN. From your study of that TRAMAN, you know that a profile is the representation of something in outline. When applied to roads, this means that a profile is a longitudinal-section view of the earth along the centerline, and it is always viewed perpendicular to the centerline.

As you know, profile-leveling procedures are used to determine the ground elevations at each of the station points along the center line. These elevations are recorded in the surveyor's notebook, which is used by the draftsman to prepare the profile drawing. Generally, the profile is drawn on the bottom portion of plan-and-profile paper, directly below the road plan. An example of a road profile is shown in figure 3-4.

A road grade line is also drawn on the lower portion of the plan-and-profile paper and is represented by a heavy solid line, as shown in figure 3-4. Like the profile, the grade line is a longitudinal section taken along the center line and shows the elevations to which the road is built. The grade line is normally the center-line elevations of the finished surface but may be the center-line elevations of the subgrade. If the subgrade was used, make a special note of it.

The grade lines are a series of straight lines that are connected, where necessary, by curves (called vertical

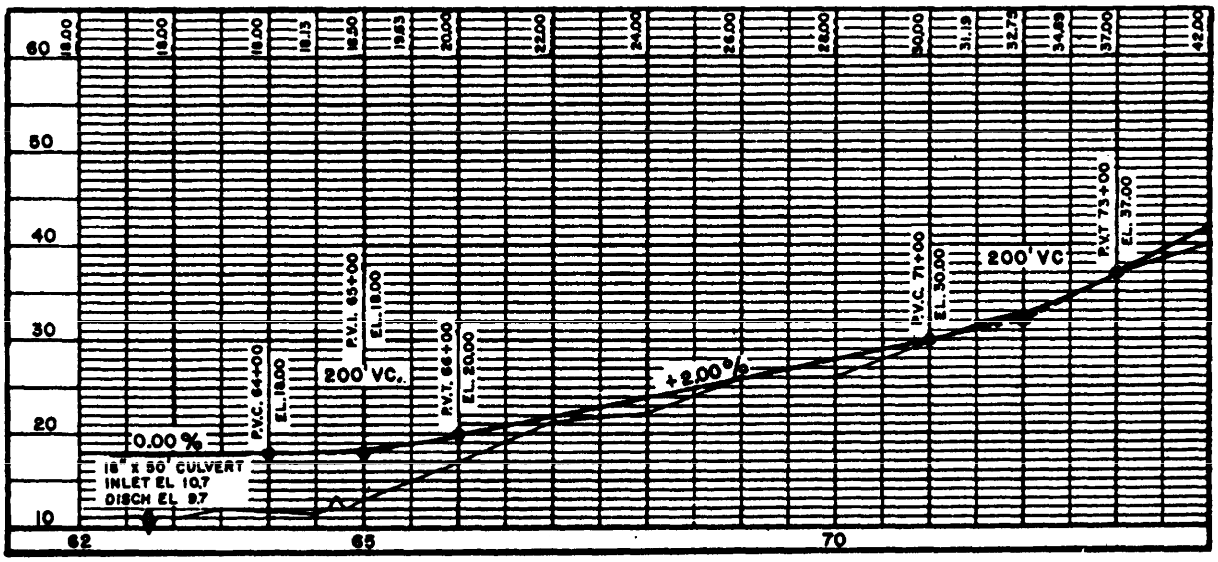


Figure 3-4.-Road profile.

curves), which will be discussed shortly. The grade lines may be level or sloped. If the lines slope upward, the grade is positive; if downward, the grade is negative. The slopes are in reference to the direction of increasing stations. The amount of slope is lettered above the grade line and is usually indicated as the percent of slope. In figure 3-4, the slope from station 66 + 00 to 71 + 00 is +2.00 percent. This means the center-line grade rises 2 feet in 100 feet horizontal distance. If the slope is -1.50 percent, the grade would fall 1.50 feet in 100 feet horizontal distance.

At vertical curves, the straight lines are tangents that intersect at a point called the **point of vertical intersection** (PVI). This point is comparable to the PI of horizontal curves.

Vertical Curves

If the road is to offer safe, comfortable driving conditions, the PVI should not break sharply. The length of the curve depends upon the steepness of the intersecting grades. In most cases, a vertical curve is symmetrical in that its length is the same on both sides of the PVI. Unlike the length of a horizontal curve, the length of a vertical curve is the horizontal distance from beginning to end of the curve, rather than the distance along the curve. The station on which the curve begins and ends is called the **point of vertical curvature** (PVC) and **point of vertical tangency** (PVT), respectively. Unlike horizontal curves, vertical curves are parabolic; they have no constant radius. Therefore, the curves are plotted, usually in 50-foot lengths, by computing the offsets from the two tangents. A vertical curve at the crest or top of a hill is called a summit **curve, or oververtical;** one at the bottom of a hill or a dip is called a **sag curve,** or **undervertical.**

Drawing the Grade Lines

You should use the same horizontal and vertical scale to draw the grade line as to draw the profile. 'Ibis allows the amount of cut or fill for a particular point to be measured. If the grade line is higher than the profile, fill is required; if lower, cut is required.

The profile and grade-line drawings also show the relative locations of drainage structures, such as box culverts and pipe. You use only the vertical scale to draw these structures. You can plot the heights of the structures accurately, using the vertical scale. However, because of the exaggerated difference between the vertical and horizontal scales, you cannot draw the width of the structures to scale. Therefore, you should draw the width of the structures just wide enough to indicate the type of structure. You should show a box culvert as a high, narrow rectangle and a round pipe as a high, narrow ellipse.

ROAD DIMENSIONS

The type of dimensioning used for road plans is a variation of the standard dimensioning. In road dimensioning, numerical values for elevations, cuts, fills, and stations are considered dimensions also. Most road dimensions appear on the profile and grade-line

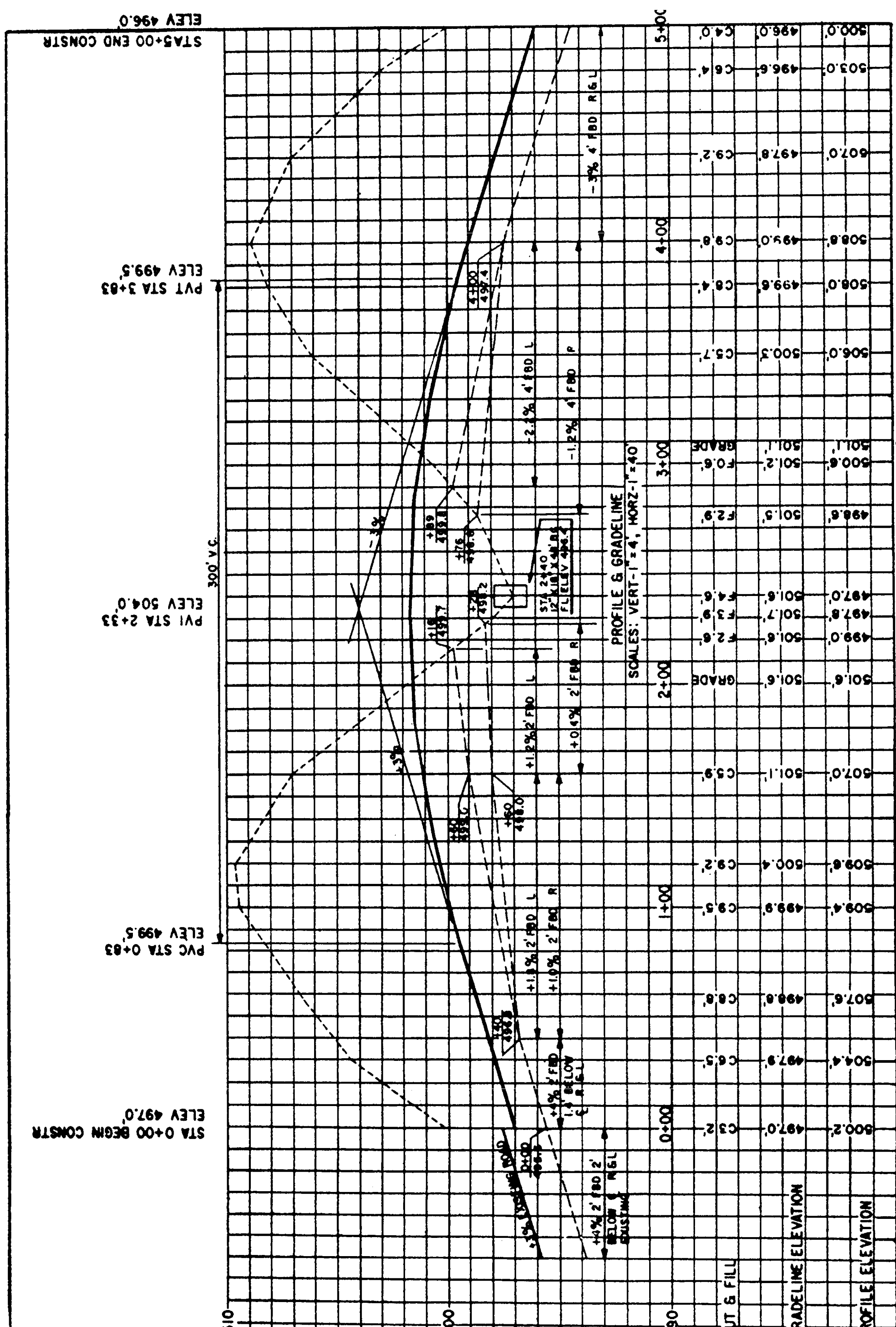


Figure 3-5.—Profile and grade line.

drawing. Refer to the example in figure 3-5, and read the following explanation:

1. **STATION NUMBERS.** The station numbers are lettered horizontally below the profile and grade line and are centered on the appropriate vertical grid line.

2. **ELEVATIONS.** At the bottom of the sheet, the profile and grade-line elevations for each station are lettered vertically. The grade-line elevations are lettered just above the profile elevations. Any station numbers other than full stations are noted as plus stations, vertically, just outside the bottom border.

3. **CUTS AND FILLS.** Above the profile and grade-line elevations are lettered the cuts and fills. They are also in a vertical position. The grade points, or points where the profile crosses the grade line, are also noted in this row. They are designated by the word *GRADE* lettered vertically above the grade-point station.

4. **DITCHES.** The procedure for dimensioning ditches has two steps as follows:

a. First, draw extension lines from the ends of a ditch or any point in the ditch where the ditch grade changes. These lines should be extended downward, and dimension lines (with heavy arrowheads) should be drawn between them. These extension and dimension lines should be drawn heavier than normal so they may be distinguished from grid lines.

b. Next, above the dimension line, letter the information necessary to describe the ditch. If the lettering is crowded, you may also use the space below the line. You should furnish the following information: percent of grade of the ditch, depth relative to center line, type of ditch, and width of ditch. Give the elevation and station at the ends of the ditches and at changes of grade.

5. **VERTICAL CURVES.** Each vertical curve on the grade line is also dimensioned. Draw extension lines upward from the PVC and PVT. Then draw a dimension line between the extension lines and letter the length of the curve above. Letter the station and elevation of the PVC, PVI, and PVT vertically over these points and above the dimension line.

6. **CORRELATION WITH PLAN.** All points on the profile and grade line coincide with center-line points on the plan. For example, you should show the beginning and ending of construction on the plan view and also on the profile and grade line. Also, note the elevations at these points.

7. **DRAINAGE STRUCTURES.** Dimension all drainage structures, such as pipes and culverts, by notes. Note the station number, size of opening, length of pipe, and flow-line elevation.

8. **TITLE.** In this example, the title, "PROFILE AND GRADE LINE is lettered below the ditch dimensions. Below this are noted the horizontal and vertical scales.

SEQUENCE OF CONSTRUCTION

In constructing a road, the construction crews should follow a specific sequence. First, they clear the area through which the road must pass of trees, stumps, brush, boulders, and other debris. The width of the clearing varies greatly but is always at least 12 feet greater than the roadway width; that is, the crew should clear at least 6 feet behind the construction limit on both sides of the road.

The next step is the grading operations and the laying of cross-drain pipes, or culverts. The grading operations are carried on by the Equipment Operators until the subgrade is completed. In fill areas, the grading is brought up in layers and compacted. In cuts, the excavation is carried on until the subgrade elevation is reached, and then the earth is compacted. Throughout this step of the road construction, workers place the culverts when and where required. These culverts are placed in their appropriate positions and at the required slopes according to the roadway plans.

After the subgrade is completed, Equipment Operators place abase course on the subgrade. The base course material can be gravel, sand, crushed stone, or more expensive and permanent materials. Finally, the Equipment Operators place a surface course over the base. This material can be sand, asphalt, blacktop, concrete, or similar materials.

In some cases, traffic may be allowed to travel over the subgrade itself. In others, traffic may require only a gravel or stone surface. A high-speed road, however, requires abase and a hard, durable surface.

SECTIONS

As you should recall from your study of the EA3 TRAMAN, a section is a view of an object that has been cut by a plane that is perpendicular to the line of sight. For road sections, the line of sight is perpendicular to the roadway center line.

Sections are used for a variety of purposes during the various phases of road design and construction. One purpose is to define what the materials and design

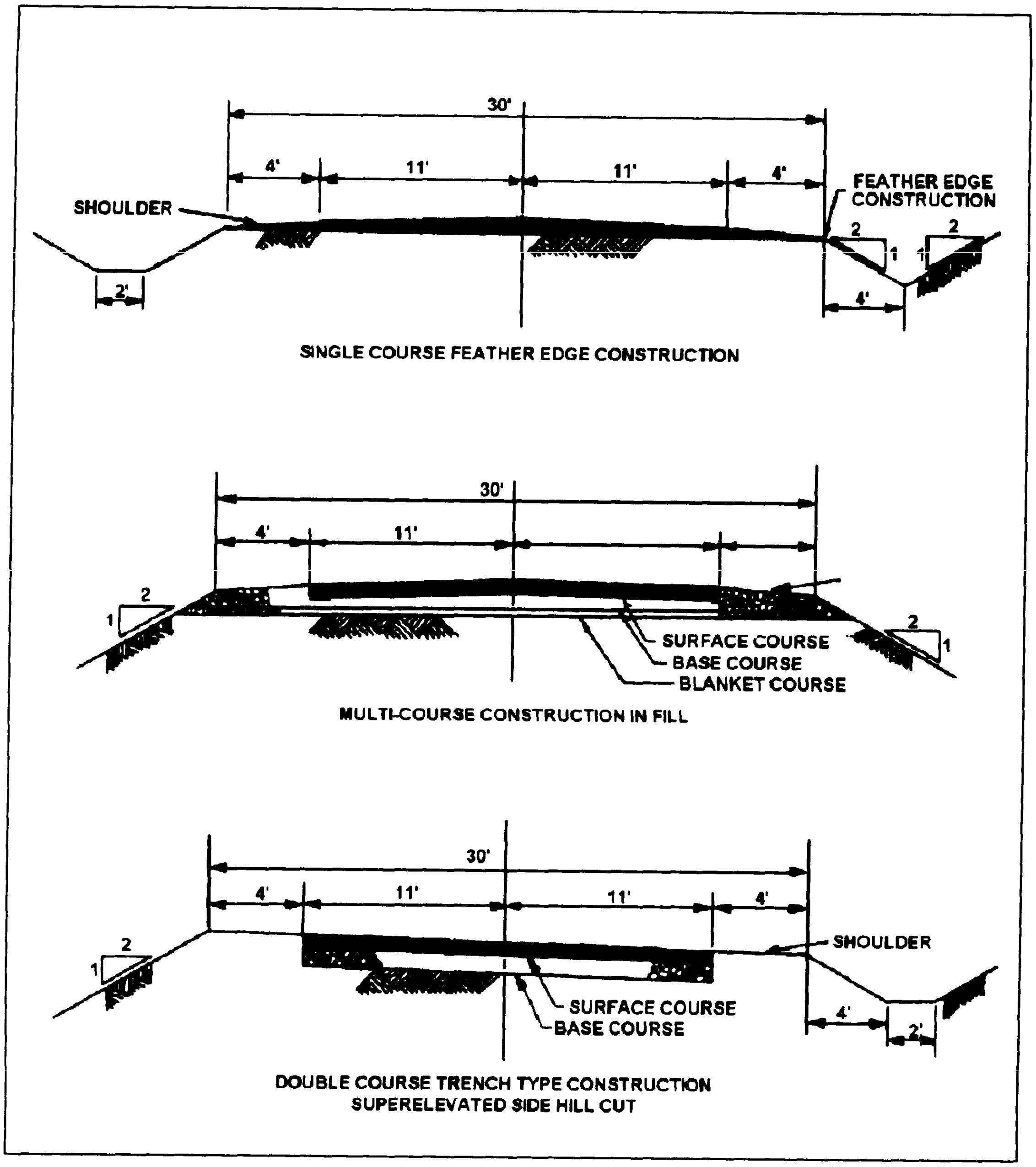


Figure 3-6.—Typical section.

configuration of the completed road should be. You will also use sections for staking out roads, for determining earthwork requirements, and for determining how closely the completed road conforms to its original design.

Typical Section

In the construction of a road, certain conditions or requirements must be met. One requirement is that the shape and features of the road be as uniform as possible. This and other requirements are stipulated in the typical section for the road. (See fig. 3-6.)

The typical section of a road shows exactly what the road should look like after it is constructed. It includes the type and thickness of the base and surface materials, the crown, superelevation, ditch slope, cut slope, fill slope, and all horizontal widths of components, such as surface, shoulders, and ditches. Since slight deviations will occur during construction, a tolerance in construction is allowed. However, the shape and construction of the road should conform as closely as possible to the typical section. (For general provisions and design criteria, refer to NAVFAC DM-5.5.)

Typical sections are prepared for both straight and curved portions of the road. The typical section for a curved portion of a road differs from the straight portion in that the shape of the roadbed is different. In a typical

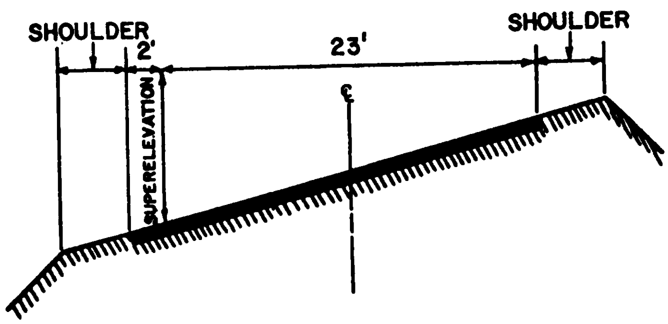


Figure 3-7.-Curve section.

section for a curve, the pavement is a plane surface instead of crowned and is usually superelevated to account for centrifugal force encountered in curves. The outside shoulder slope is the same as the superelevated pavement slope, but the inside shoulder slope is either the same or greater slope. (Inside shoulder refers to the shoulder closest to the center of the arc, or curve.)

Most curves are also widened on the inside to allow for the "curve straightening" effect of long wheelbase vehicles. The back wheels of the trailer in a tractor-trailer rig do not follow in the tracks of the tractor wheels. They run closer to the inside edge on the inside lane and closer to the centerline on the outside lane. This presents a safety hazard when two vehicles meet in curves. Curve widening partially eliminates this hazard.

Figure 3-7 is a superelevated section showing curve widening. Specific guidance for curve widening is contained in NAVFAC DM-5.5.

Preliminary Cross Section

Preliminary cross sections are sectional views of the existing terrain taken at each station point along the center line of the route the road is to take. These sections are usually taken after the roadway has been cleared but may be taken before. If the sections are taken before, the thickness of the sod to be stripped off is normally deducted from the elevations. The preliminary cross section shows the elevations of the natural, or original, ground. These sections, when superimposed on the desired finished roadbed sections, are used for studying various alignments of the road and for preliminary earthwork estimating. Figure 3-8 shows typical preliminary cross sections.

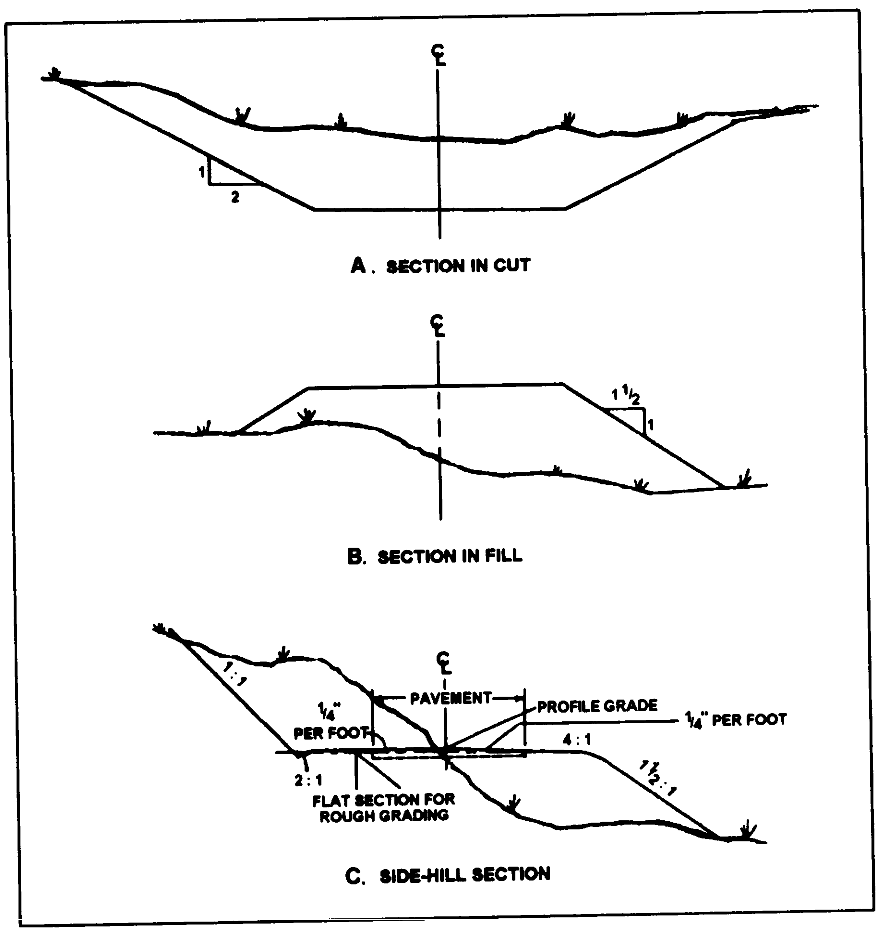


Figure 3-8.—Preliminary cross sections.

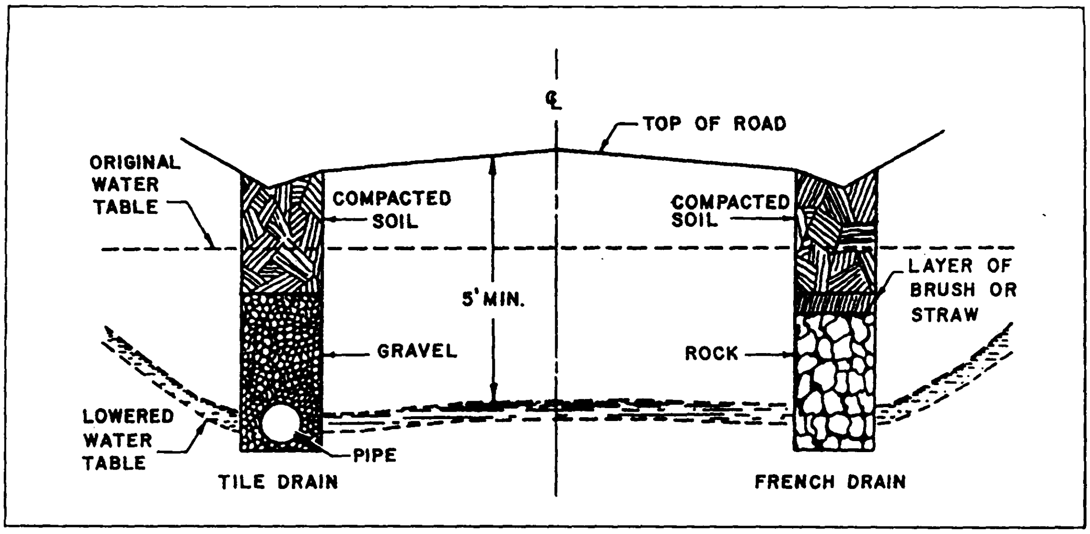


Figure 3-9.-Subsurface drainage.

Final Cross Section

When the final vertical and horizontal alignments of the road are fairly well fixed, final design is commenced. During this phase, final construction drawings are prepared and construction may begin. Before actual construction starts, **final cross sections** are prepared. From these final cross sections, slope stakes are set as described in the EA3 TRAMAN. Final cross sections are taken at each station along the center line of the road. They show the actual shape of the road, the horizontal width of components and their distances from the center line, the finish elevations, and the extremities of the cut and fill. They also show the slopes of the roadbed surface, ditches, and shoulders. The term *final cross section* is also applied to the **as-built** sections that are taken after the road is completed.

The procedures used to plot cross sections are discussed in chapter 14 of the EA3 TRAMAN. You should review that chapter if you are unsure of the procedures.

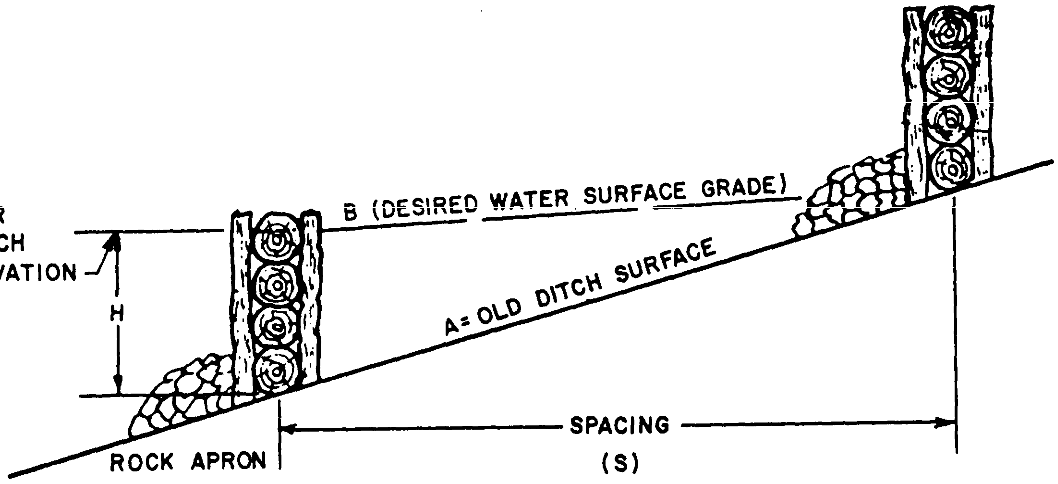
DRAINAGE

Drainage is a major problem in the location, construction, and design of roads. A route should never be located where the drainage presents a problem that cannot be handled or would be too costly to handle. A route may have to be relocated because there is not enough material available to build a particular type of road. It may also have to be relocated because of a swamp or underground spring, high flood waters that can cover the road, or flash floods that can completely wash out the road. These are some of the reasons for planning alternate routes. During construction, the problem of drainage is mainly one of preventing standing puddles on the roadway. This problem is solved by slanting the worked surface of the road so that water can run off quickly or by cutting ditches, called bleeders, so that the water maybe carried away as it accumulates.

Subsurface drainage problems are solved by raising the grade line of the road or lowering the water table. In either case, the distance between the water table and the top of the subgrade should be as great as possible. There are several ways of lowering the water table. In one way, deep, open ditches are set back beyond the roadway limits. These ditches intercept the water table, allowing groundwater to seep through the sides. The water then flows along the bottom and out the end of each ditch

In another way of lowering the water table, a deep trench is dug exactly where the finished roadway ditch would be. The trench is then backfilled to a designated depth with rocks or large gravel of varying size, with the larger size at the bottom. The rocks are capped with a layer of branches or straw and the remainder of the trench backfilled with soil and compacted This trench is called a **french drain** (fig. 3-9). A tile drain, also shown in figure 3-9, is the same as a french drain except that a perforated pipe or tile is placed in the bottom of the trench. The trench is then backfilled with gravel to the desired depth. The minimum pipe grade is 0.3 percent with the maximum varying to meet conditions.

Surface drainage involves water from direct precipitation, surface runoff, rivers, and streams. (Surface runoff is rainfall that is not absorbed by the soil but runs off a surface in sheets or rivulets.) Rainfall has an immediate effect upon a roadway. Obviously, rainwater would be a safety hazard or cause weak spots on the roadway if it were allowed to stand. Water that



$$S = \frac{100\ H}{A-B}$$

Where H = height of checkdam in feet, measured from bottom of weir notch to bottom of ditch.

A = % grade of existing ditch.
B = desired % grade of proposed water surface.
(H can vary from 1 to 3 feet. A is usually known
B should be between 0.5% and 4%– desirably, 2%).

Figure 3-10.-Check dams.

falls upon the surface, or traveled way, is drained by crowning the surface; that is, constructing the traveled way so that the middle is higher than the edges.

The traveled way in curves is drained by superelevating the surface; that is, constructing the traveled way so that the inside edge of the curve is lower than the outside edge.

The water that drains from the surface continues over the shoulders. The shoulders always have a slope greater than, or at least equal to, the surface slope. This slightly increases the speed of the draining water and therefore increases the rate of drainage. The water then flows from the shoulder down the side of the fall, if in a fill section of a roadway. If the section is in a cut, the water flows into a roadway ditch. Roadway ditches are not normally in a fill section.

Roadway Ditches

The functioning of a roadway ditch is the most important factor in roadway drainage. If this ditch, which runs alongside the roadway, becomes obstructed or is inadequate for the volume of water, then the roadbed becomes flooded. Not only can this block traffic, but it can also wash away surface and shoulder material.

There are several factors to consider in determining the size and type of roadway ditches, such as volume of water to be carried, the slope of the backslope, soil types, the "lay of the land," and the maximum and minimum ditch grades.

The slopes of the surface, shoulders, and backslopes affect the volume. A steep slope increases the rate of runoff, thereby causing a greater instantaneous volume of water in the ditch. On the other hand, a lesser slope decreases the rate of runoff but exposes more surface area on the backslope, which increases the amount of runoff.

The choice of slopes to be used is governed by other factors, however. The foremost factors are whether the additional excavation is needed in the roadway construction and the type of soil. A lesser slope would be required if the cut is in sand instead of clay or rock. The usual cut slope, or backslope, is 1 1/2:1 (1 1/2 foot horizontal, 1 foot vertical). This slope maybe decreased for sandy soil or greatly increased for rock cuts. The usual ditch slope, from the shoulder to the bottom of the ditch, is 3:1. All these soil types have different amounts of runoff. The runoff from a sandy soil is small, but from a clay soil or solid rock it is large.

An important design factor is the ditch grade itself. The minimum grade is 0.5 percent, and the desirable maximum grade is 4 percent. A grade greater than 4 percent would cause excessive erosion due to the greater velocity of the water. In this case, low dams of wood or stones, called check dams (fig. 3-10), are built across

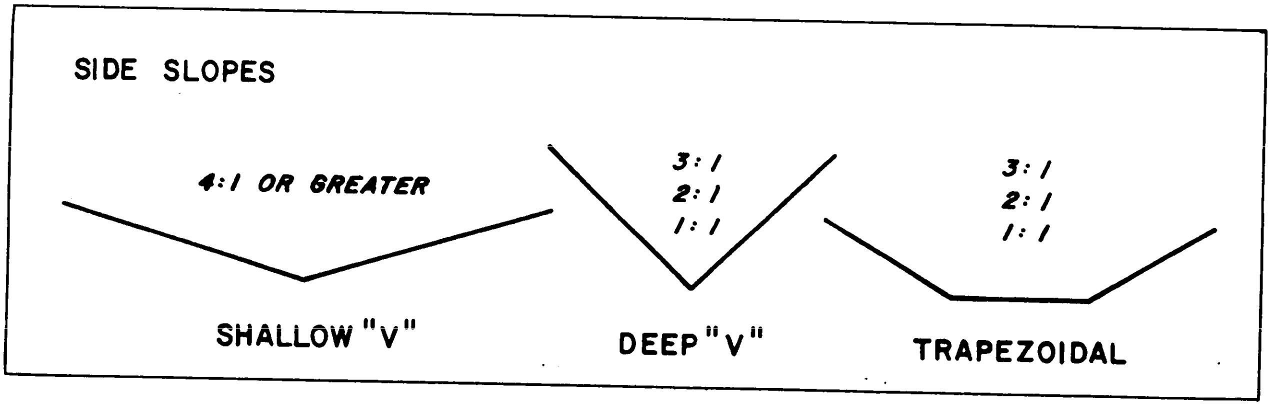


Figure 3-11.—Types of ditches

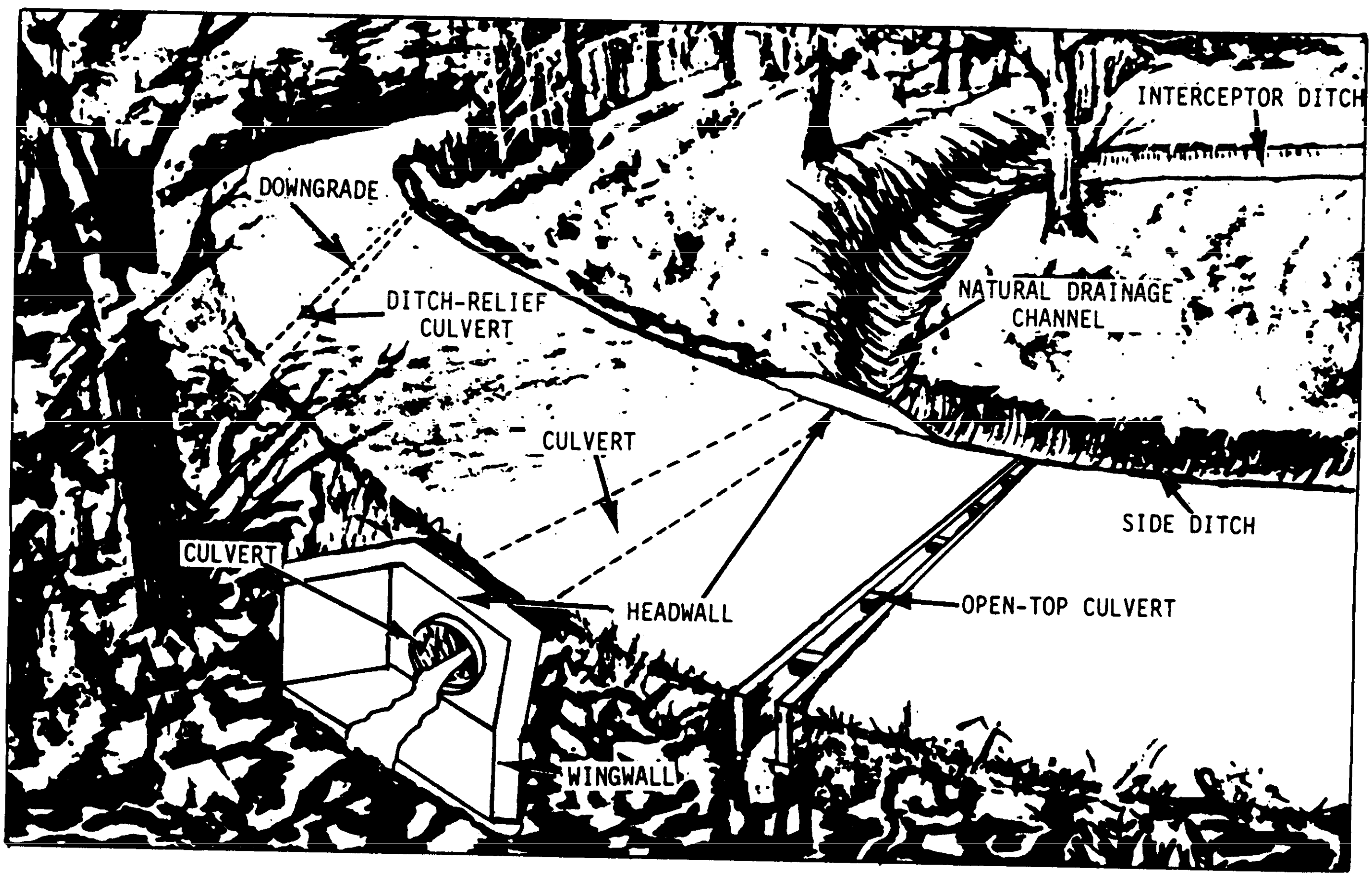


Figure 3-12.—Drainage systems.

the bottom of the ditch to slow down the water. In general, a moderate velocity is desirable because it prevents excessive erosion and can offset the pending effect of slower moving water.

One factor involving the volume of water that cannot be controlled is the rainfall itself. The more intense the rainfall and the longer the duration, the greater the volume of water the ditch has to carry. Talking to local residents and observing high-water marks along streams are helpful to the engineer in determining the heaviest rainfall to expect in a particular area.

The engineer must consider not only the factors involving the volume of water but also the design of the ditch itself. Two common types of ditches are the V-bottom and the flat bottom, or trapezoidal, ditch. Examples of these ditches are shown in figure 3-11. Under similar conditions, water flows faster in a V-bottom ditch than in a trapezoidal ditch. The side slope for a shallow V-bottom ditch is 4:1 or greater. For

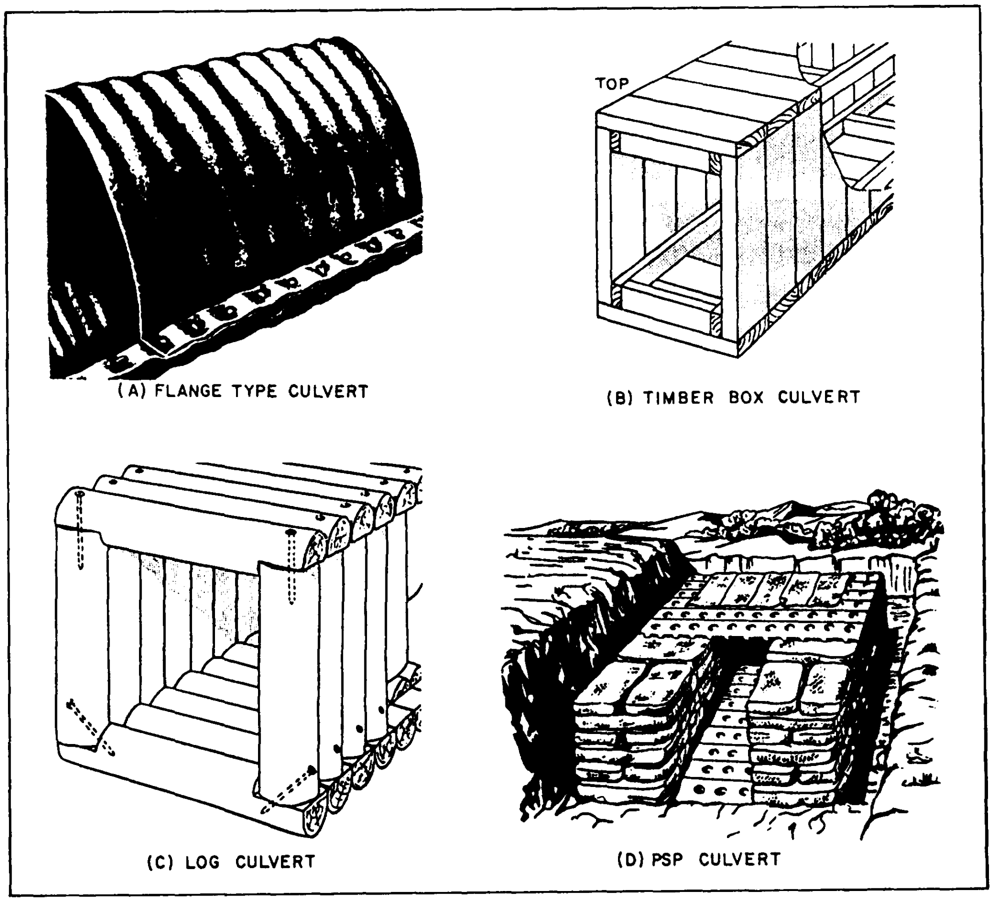


Figure 3-13.-Types of culverts.

a deep V-bottom ditch, the side slope is 3:1, 2:1, or 1:1. The side slope for a trapezoidal ditch is 3:1,2:1, or 1:1. The flat bottom is generally 2 feet wide but can range from 1 foot to 6 feet or more.

Interceptor Ditches

The volume of water draining into a roadway ditch can be decreased by the use of shallow ditches that extend around the top of the cut and intercept the water draining from the original ground toward the roadway. An interceptor ditch shown in figure 3-12 is dug 2 or 3 feet behind the backslope limits. Its size depends on the original ground slope, runoff area, type of soil and vegetation, and other factors related to runoff volume.

Diversion Ditches

As it leaves the cut, water from the roadway ditches cannot be allowed to pond in the ditches or against the roadway fill. Therefore, diversion ditches are dug to carry the water away from the roadway to natural drains. These drains can be rivers, streams, gullies, sinkholes, natural depressions, or hollows.

Culverts

Sometimes it is necessary to have the water flow from one side of the road to the other or have the road cross a small stream. You do this with cross drains. They are called culverts if they are 10 feet or less in width. Over 10 feet wide, they are called bridges. Culverts are made of many materials, such as corrugated metal, reinforced concrete, concrete pipe, timber, logs, and even open-ended oil drums. The type of material selected is dependent upon various factors including, in part, the type and life expectancy of the road.

For permanent roads and highways with concrete or asphalt paving, the most durable of materials, such as reinforced concrete or concrete pipe, should be used. Concrete pipe is one of the strongest and most durable materials used in making culverts. The shell thickness and length depend on the pipe diameter. (The larger the diameter, the thicker the shell and longer the section.) Pipe diameters are nominal inside dimensions. For semipermanent and temporary roads, the design engineer may choose to use materials such as those shown in figure 3-13.

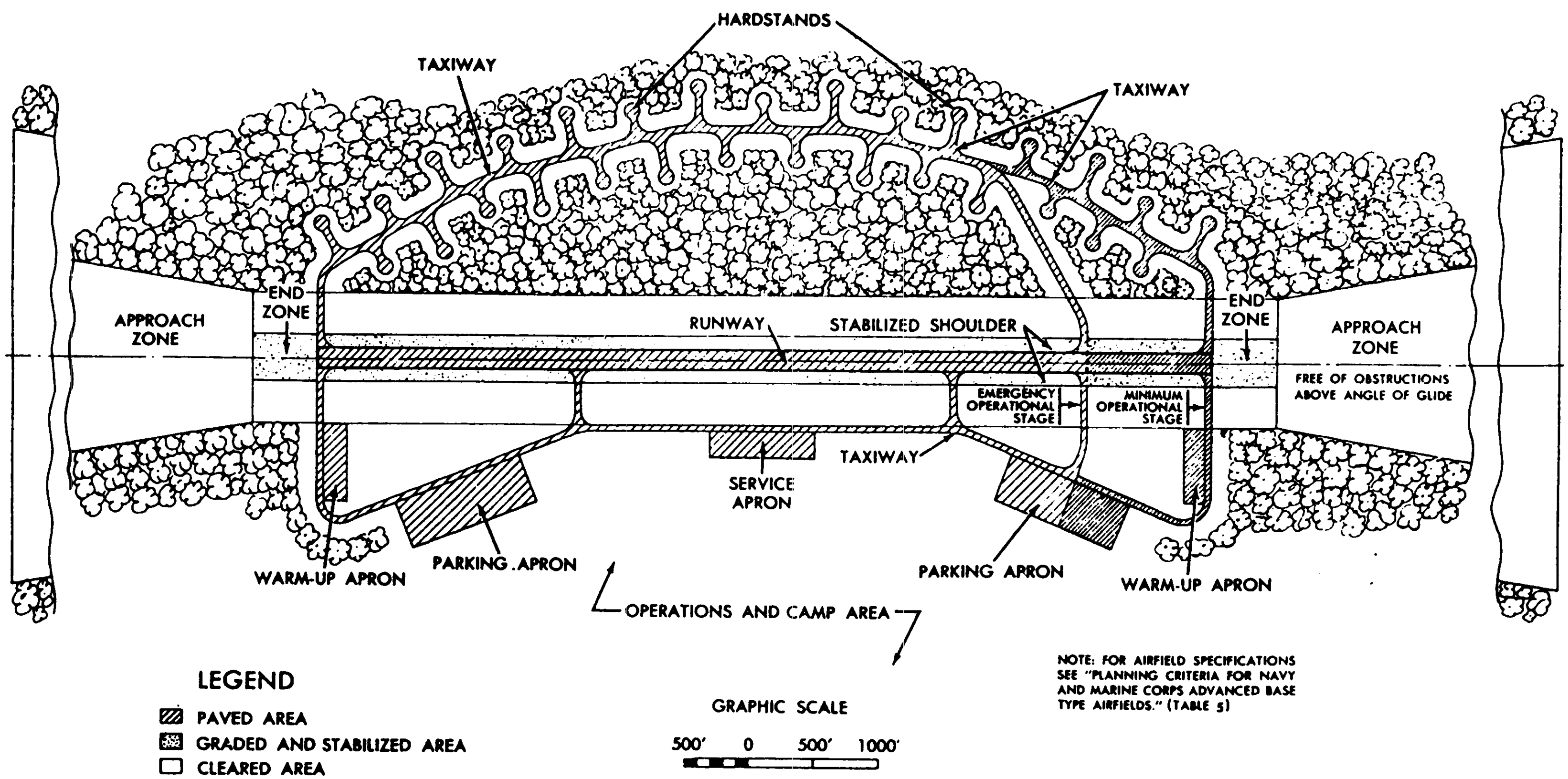


Figure 3-14.—Plan view of an advanced-base airfield.

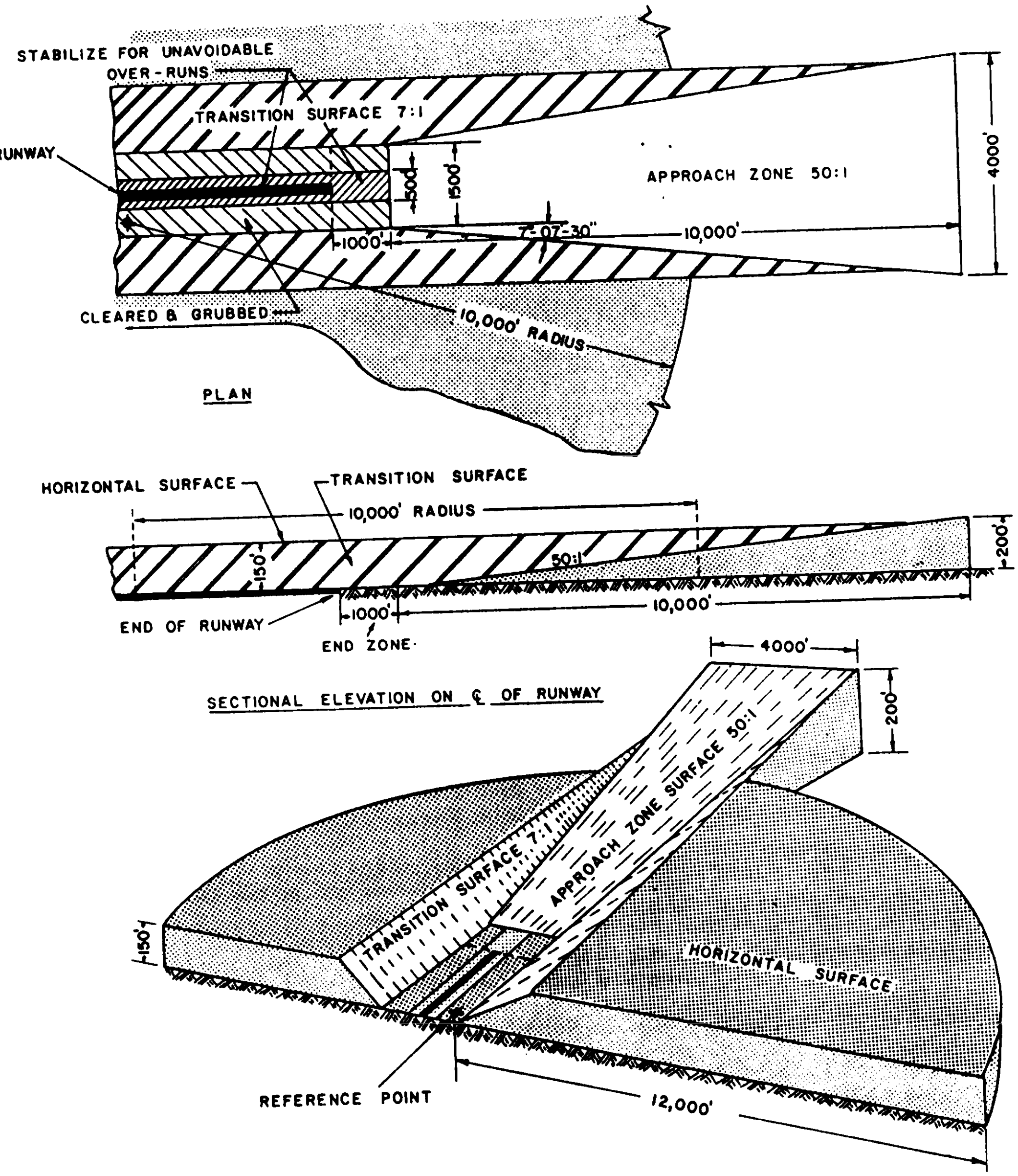


Figure 3-15.-Runway approach zone.

AIRFIELDS

Road construction and airfield construction have much in common, such as construction methods, equipment used, and sequence of operations. Each road or airfield requires a subgrade, base course, and surface course. The methods of cutting and falling, grading and compacting, and surfacing are all similar. As with roads, the responsibility for designing and laying out lies with the same person-the engineering officer. Again, as previously said for roads, you can expect involvement when airfield projects occur.

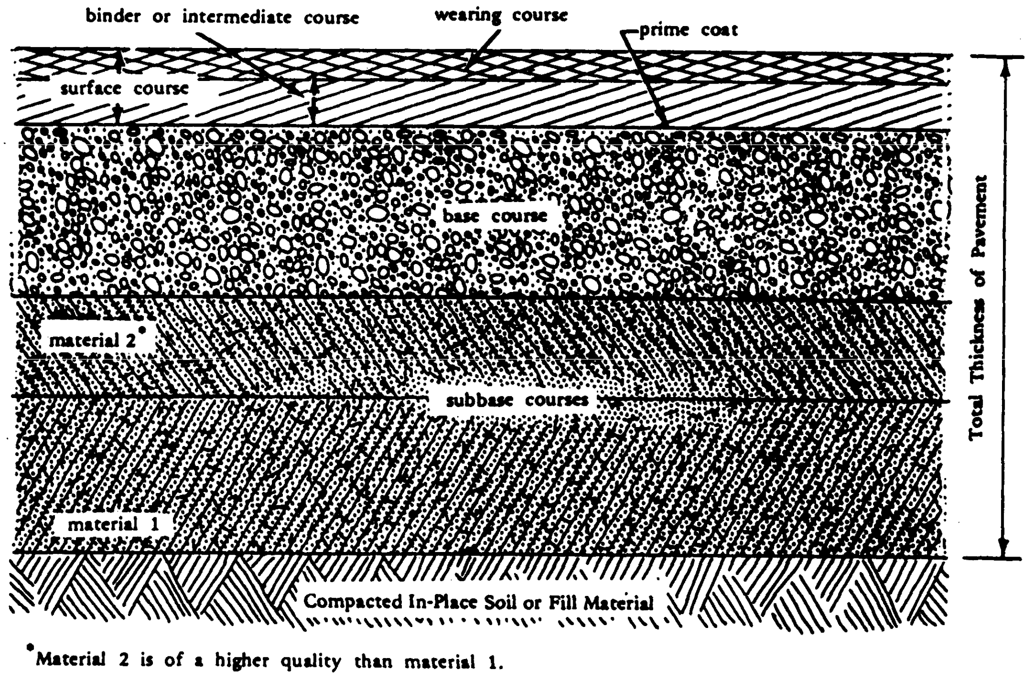
In this section, you will be introduced to airfields and airfield terminology. More information on airfields will be discussed in a later chapter of this TRAMAN.

AIRFIELD TERMINOLOGY

Figure 3-14 is a plan view of a small advanced-base airfield. Afield of this type is constructed for operational use in a combat area. It contains a minimum of servicing facilities and is not intended for permanent occupancy. Some of the terms shown in the figure are defined as follows:

APPROACH ZONE. A trapezoidal area established at each end of a runway. The approach zone must be free of obstructions on the plane of a specific glide angle. (See fig. 3-15.)

APRON. A stabilized, paved or metal-plank surface area, designed for the temporary parking of aircraft



PAVEMENT	Combination of subbase, base, and surface constructed on subgrade
SURFACE COURSE	A hot mixed bituminous concrete designed as a structural member with weather and abrasion resisting properties. May consist of wearing and intermediate courses.
PRIME COAT	Application of a low viscosity liquid bitumen to the surface of the base course. The prime penetrates into the base and helps bind it to the overlying bituminous course
SEAL COAT	A thin bituminous surface treatment containing aggregate used to waterproof and improve the texture of the surface course
COMPACTED SUBGRADE	Upper part of the subgrade which is compacted to a density greater than the soil below
TACK COAT	A light application of liquid or emulsified bitumen on an existing paved surface to provide a bond with the superimposed bituminous course
SUBGRADE	Natural in-place soil, or fill material

Figure 3-16.—Typical flexible pavement and terminology.

other than at hardstands. Aprons are classified as service, **warm-up,** and **parking.**

END ZONE. A cleared and graded area that extends beyond each end of the runway. The dimensions of the end zone depend upon the safety clearances specified by the design criteria for advanced-base airfields. (See fig. 3-15.)

GLIDE ANGLE. The angle between the flight path of an airplane during a glide for landing or takeoff and a horizontal plane fixed relative to the runway. The glide angle is measured from the outer edge of the end zone. (See fig. 3-15.)

HARDSTAND. A stabilized, paved, or metal-plank-surfaced parking area of sufficient size and strenght tp accomodate a limited number of aircraft. Handstands are usually dispersed over the ground area beyond the safety clearance zones of a landing strip. They provide protection for aircraft on the field by dispersal, concealment, and revetment

LANDING AREA. The paved portion, or runaway, of the landing field. The landing area should have unobstructed approaches and should be suitable for the safe landing and takeoff of aircraft under ordinary weather conditions.

LANDING STRIP. Includes the landing area, end zones, shoulders, and cleared areas.

REVETMENT. A protective pen usually made by excavating into the side of a hill or by constructing earth, timber, sandbag, or masonry traverse around the hardstands. Such pens provide protection against bomb fragments from high-altitude bombing but provide little protection against ground strafing. They may actually draw this type of fire if they are not well concealed.

RUNWAY. That portion of the landing strip, usually paved, that is used for the landing and takeoff of aircraft.

SHOULDER. The graded and stabilized area adjacent to the runway or taxiway. Although it is made capable of supporting aircraft and auxiliary equipment (such as crash trucks) in emergencies, its principal function is to facilitate surface drainage.

TAXIWAY. A specially prepared area over which aircraft may taxi to and from the landing area.

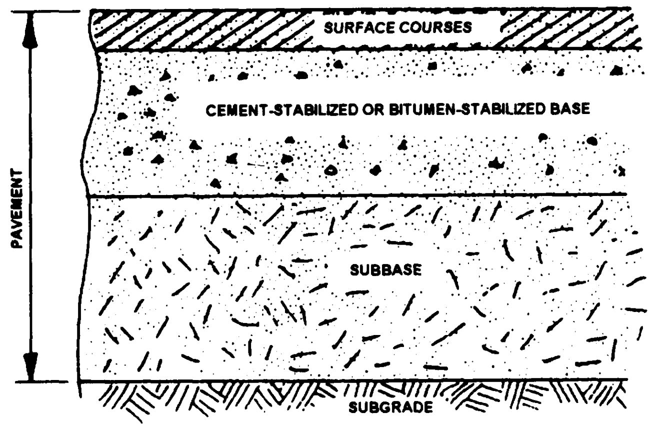
TRANSITION SURFACE. A sloping plane surface (about 1 foot rise to 7 feet run) at the edge of a landing strip. Its function is to provide lateral safety clearances for planes that accidental] y run off the strip. (See fig. 3-15.)

PLANNING AN AIRFIELD

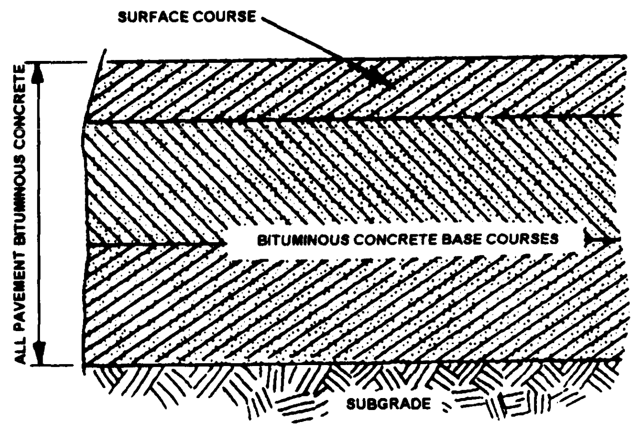
Planning for aviation facilities requires special consideration of the type of aircraft to be accommodated; physical conditions of the site, including weather conditions, terrain, soil, and availability y of construction materials; safety factors, such as approach zone obstructions and traffic control; the provision for expansion; and defense. Under wartime conditions, tactical considerations are also required. All of these factors affect the number, orientation, and dimensions of runways, taxiways, aprons, hardstands, hangars, and other facilities.

SUBBASE AND BASE COURSE

Pavements (including the surface and underlying courses) may be divided into two classes—rigid and flexible. The wearing surface of a rigid pavement is constructed of portland cement concrete. Its flexural strength enables it to act as abeam and allows it to bridge over minor irregularities in the base or subgrade upon which it rests. All other pavements are classified as flexible. Any distortion or displacement in the subgrade of a flexible pavement is reflected in the base course and upward into the surface course. These courses tend to conform to the same shape under traffic. Flexible pavements are used almost exclusively in the theater of operations for road and airfield construction since they adapt to nearly all situations and can be built by any construction battalion unit in the Naval Construction Force (NCF).



STABILIZED BASE SECTION



ALL BITUMINOUS CONCRETE PAVEMENT

Figure 3-17.-Typical pavements using stabilized layers.

FLEXIBLE PAVEMENT STRUCTURE

A typical flexible pavement is constructed as shown in figure 3-16, which also defines the parts or layers of pavement. All layers shown in the figure are not present in every flexible pavement. For example, a two-layer structure consists of a compacted subgrade and a base course only. Figure 3-17 shows a typical flexible pavement using stabilized layers. (The word *pavement,* when used by itself, refers only to the leveling, binder, and surface course, whereas *flexible pavement* refers to the entire pavement structure from the subgrade up.) The use of flexible pavements on airfields must be limited to paved areas not subjected to detrimental effects of jet fuel spillage and jet blast. In fact, their use is prohibited in areas where these effects are severe.

Flexible pavements are generally satisfactory for runway interiors, taxiways, shoulders, and overruns. Rigid pavements or special types of flexible pavement, such as tar rubber, should be specified in certain critical operational areas.

MATERIALS

Select materials will normally be locally available coarse-grained soils, although fine-grained soils maybe used in certain cases. Lime rock, coral, shell, ashes, cinders, caliche, disintegrated granite, and other such materials should be considered when they are economical.

Subbase

Subbase materials may consist of naturally occurring coarse-grained soils or blended and processed soils. Materials, such as lime rock, coral, shell, ashes, cinders, caliche, and disintegrated granite, maybe used as subbases when they meet area specifications or project specifications. Materials stabilized with commercial admixes may be economical as subbases in certain instances. Portland cement, cutback asphalt, emulsified asphalt, and tar are commonly used for this purpose.

Base Course

A wide variety of gravels, sands, gravelly and sandy soils, and other natural materials such as lime rock, corals, shells, and some caliches can be used alone or blended to provide satisfactory base courses. In some instances, natural materials will require crushing or removal of the oversize fraction to maintain gradation limits. Other natural materials may be controlled by mixing crushed and pit-run materials to form a satisfactory base course material.

Many natural deposits of sandy and gravelly materials also make satisfactory base materials. Gravel deposits vary widely in the relative proportions of coarse and fine material and in the character of the rock fragments. Satisfactory base materials often can be produced by blending materials from two or more deposits. Abase course made from sandy and gravel] y material has a high-bearing value and can be used to support heavy loads. However, uncrushed, clean washed gravel is not satisfactory for a base course because the fine material, which acts as the binder and fills the void between coarser aggregate, has been washed away.

Sand and clay in a natural mixture maybe found in alluvial deposits varying in thickness from 1 to 20 feet. Often there are great variations in the proportions of sand and clay from the top to the bottom of a pit. Deposits of partially disintegrated rock consisting of fragments of rock, clay, and mica flakes should not be confused with sand-clay soil. Mistaking such material for sand-clay is often a cause of base course failure because of reduced stability caused by the mica content. With proper proportioning and construction methods, satisfactory results can be obtained with sand-clay soil. It is excellent in construction where a higher type of surface is to be added later.

Processed materials are prepared by crushing and screening rock, gravel, or slag. A properly graded crushed-rock base produced from sound, durable rock particles makes the highest quality of any base material. Crushed rock may be produced from almost any type of rock that is hard enough to require drilling, blasting, and crushing. Existing quarries, ledge rock, cobbles and gravel, talus deposits, coarse mine tailings, and similar hard, durable rock fragments are the usual sources of processed materials. Materials that crumble on exposure to air or water should not be used. Nor should processed materials be used when gravel or sand-clay is available, except when studies show that the use of processed materials will save time and effort when they are made necessary by project requirements. Bases made from processed materials can be divided into three general types-stabilized, coarse graded, and macadam. A stabilized base is one in which all material ranging from coarse to fine is intimately mixed either before or as the material is laid into place. A coarse-graded base is composed of crushed rock, gravel, or slag. This base may be used to advantage when it is necessary to produce crushed rock, gravel, or slag on site or when commercial aggregates are available. A macadam base is one where a coarse, crushed aggregate is placed in a relatively thin layer and rolled into place; then fine aggregate or screenings are placed on the surface of the coarse-aggregate layer and rolled and broomed into the coarse rock until it is thoroughly keyed in place. Water may be used in the compacting and keying process. When water is used, the base is a water-bound macadam. The crushed rock used for macadam bases should consist of clean, angular, durable particles free of clay, organic matter, and other objectional material or coating. Any hard, durable crushed aggregate can be used, provided the coarse aggregate is primarily one size and the fine aggregate will key into the coarse aggregate.

Other Materials

In a theater of operations where deposits of natural sand and gravel and sources of crushed rock are not available, base courses are developed from materials that normally would not be considered. These include coral, caliche, tuff, rubble, lime rock, shells, cinders, iron ore, and other select materials. Some of these are primarily soft rock and are crushed or degraded under construction traffic to produce composite base materials. Others develop a cementing action, which results in a satisfactory base. The following text describes the characteristics and usage of some of these materials:

1. **CORAL.** Uncompacted and poorly drained coral often results in an excessive moisture content and loss of stability. The bonding properties of coral, which are its greatest asset as a construction material, vary with the amount of volcanic impurities, the proportion of fine and coarse material, age, length of exposure to the elements, climate, traffic, sprinkling, and method of compaction. Proper moisture control, drainage, and compaction are essential to obtain satisfactory results.

2 **CALICHE.** A variable material that consists of sand, silt, or even gravel, that when saturated with water, compacted, and allowed to settle, can be made into high-quality base courses, especially caliches that are cemented with lime, iron oxide, or salt. Caliches vary, however, in content (limestone, silt, and clay) and in degree of cementation; therefore, it is important that caliche of good uniform quality be obtained from deposits and that it be compacted at optimum moisture.

3. **TUFF.** A porous rock usually stratified, formed by consolidation of volcanic ashes, dust, and so forth, and other cementitious materials of volcanic origin, may be used for base courses. Tuff bases are constructed the same as other base courses except that after the tuff is dumped and spread, the oversize pieces are broken and the base compacted with sheepsfoot rollers. The surface is then graded, compacted, and finished.

4. **RUBBLE.** It may be advantageous to use the debris or rubble of destroyed buildings in constructing base courses. If so, jagged pieces of metal and similar objects are removed.

Bituminous Base

Bituminous mixtures are frequently used as base courses beneath high-type bituminous pavements, particularly for rear-area Wields which carry heavy traffic. Such base courses may be used to advantage when locally available aggregates are relatively soft and otherwise of relatively poor quality, when mixing plant and bituminous materials are readily available, and when a relatively thick surface course is required for the traffic. In general, a bituminous base course may be considered equal on an inch-for-inch basis to other types of high-quality base courses. When a bituminous base course is used, it will be placed in lifts not exceeding 3 1/2 inches in thickness. If a bituminous base is used the binder course may be omitted, and the surface course may be laid directly on the base course.

QUESTIONS

Q1. What is the correct nomenclature for each of the items labeled in figure 3-18?

Q2. What feature is normally provided in a horizontal curve to counteract the effect of centrifugal force?

Q3. What type of section is used to set slope stakes and to show as-built conditions?

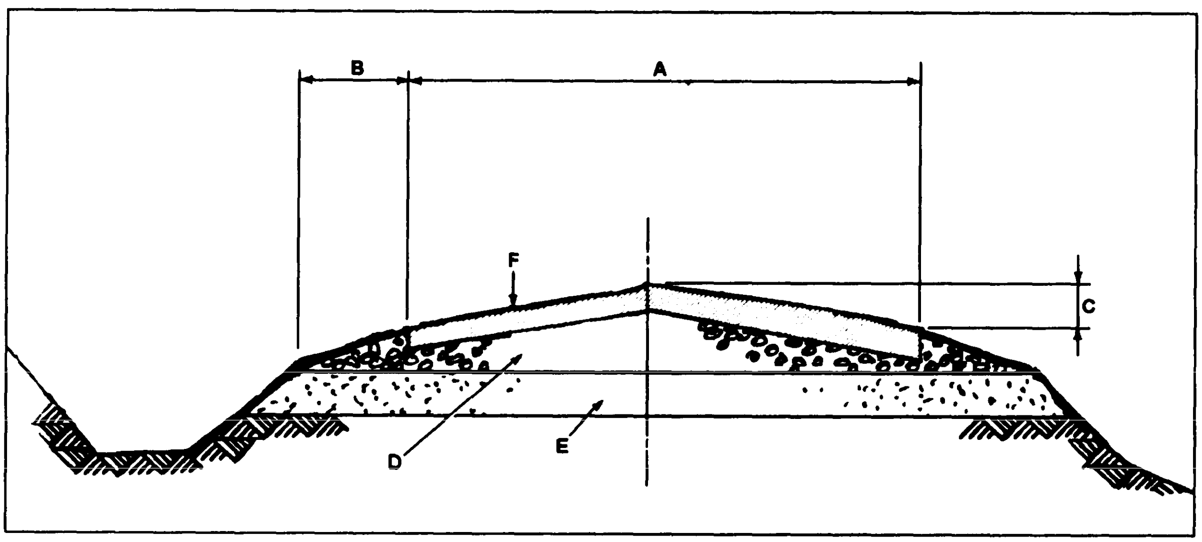


Figure 3-18.-Typical section.